Exhibit 8

Illustrative Claim Chart for U.S. Patent No. 7,739,544

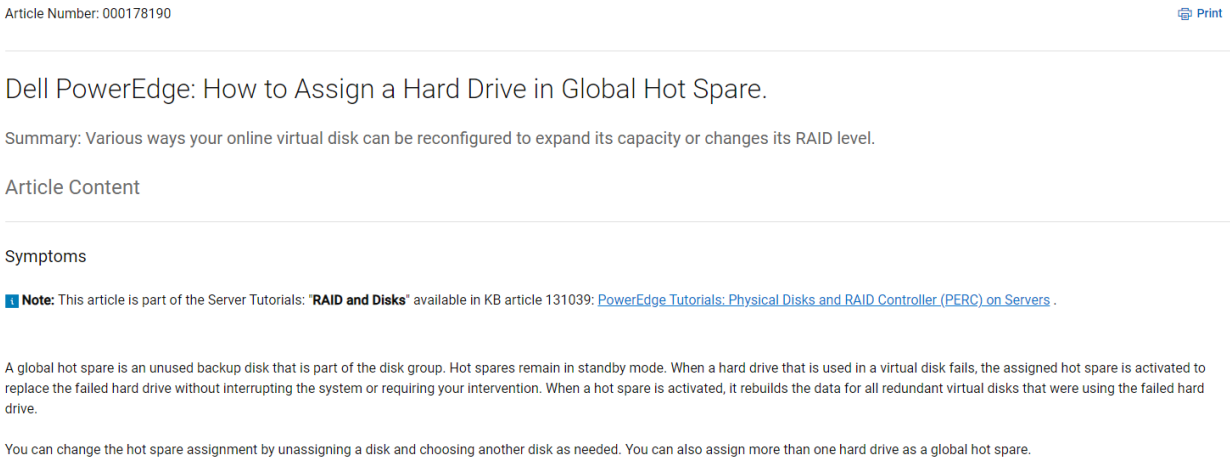
Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
A method of rebuilding a disk array system, said method comprising:	The Exemplary Dell '544 Products practice a method of rebuilding a disk array system. *See, e.g.,*: Article Number: 000128635 Print Dell Servers - What are the RAID levels and their specifications? Summary: A RAID is a group of independent physical disks. This article explains the different level of RAID (RAID 0, RAID 1, RAID 5, RAID 10, RAID 50, RAID 60) Article Content Symptoms RAID is a data storage virtualization technology that combines multiple physical disk drive components into a single logical unit for the purposes of data redundancy, performance improvement, or both. Data is distributed across the drives in one of several ways, referred to as **RAID levels**, depending on the required level of redundancy and performance. The different schemas, or data distribution layouts, are named by the word **RAID** followed by a number, for example **RAID 0** or **RAID 1.** Each schema, or RAID level, provides a different balance among the key goals: **reliability**, **availability**, **performance**, and **capacity**. RAID levels greater than RAID 0 provide **protection against unrecoverable sector read errors**, as well as against failures of whole physical drives.

[1] The 14th, 15th, and 16th Generations comprise at least the following models: R240, R340, R440, R540, R640, R6415, R740, R740xd, R740xd2, R7415, R7425, R840, R940, R940xa, R250, R350, R450, R550, R650, R650xs, R6515, R6525, R750, R750xa, R750xs, R7515, R7525, R360, R660, R660xs, R6615, R6625, R760, R760xa, R760xd2, R760xs, R7615, R7625, R860, R960. *See* illustrative documentation at https://www.dell.com/support/kbdoc/en-us/000137343/how-to-identify-which-generation-your-dell-poweredge-server-belongs-to.

[2] Many, but not all, of the PowerEdge RAID Controllers that are used by the 14th, 15th, and 16th Generations of the Dell PowerEdge Rack Servers can be found at the following URL: https://www.dell.com/support/kbdoc/en-us/000131648/list-of-poweredge-raid-controller-perc-types-for-dell-emc-systemsand. Other Dell PowerEdge RAID Controllers may also be used in conjunction with the 14th, 15th, and 16th Generations of the Dell PowerEdge Rack Servers to infringe the '544 Patent.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

"Dell Servers - What are the RAID levels and their specifications[3]," 1.



Article Number: 000178190

Print

Dell PowerEdge: How to Assign a Hard Drive in Global Hot Spare.

Summary: Various ways your online virtual disk can be reconfigured to expand its capacity or changes its RAID level.

Article Content

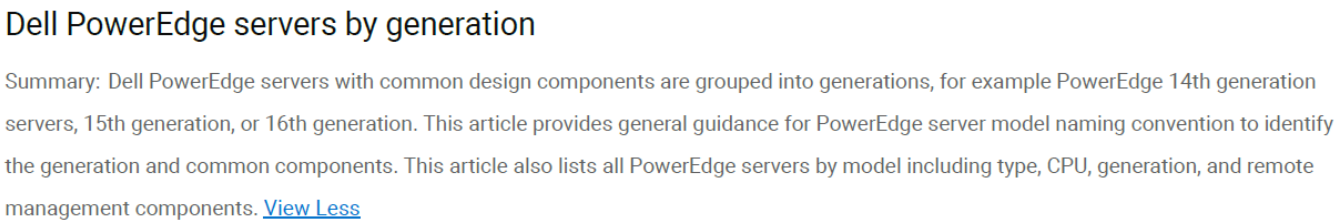
Symptoms

Note: This article is part of the Server Tutorials: "**RAID and Disks**" available in KB article 131039: PowerEdge Tutorials: Physical Disks and RAID Controller (PERC) on Servers .

A global hot spare is an unused backup disk that is part of the disk group. Hot spares remain in standby mode. When a hard drive that is used in a virtual disk fails, the assigned hot spare is activated to replace the failed hard drive without interrupting the system or requiring your intervention. When a hot spare is activated, it rebuilds the data for all redundant virtual disks that were using the failed hard drive.

You can change the hot spare assignment by unassigning a disk and choosing another disk as needed. You can also assign more than one hard drive as a global hot spare.

"Dell PowerEdge: How to Assign a Hard Drive in Global Hot Spare[4]," 1.



Dell PowerEdge servers by generation

Summary: Dell PowerEdge servers with common design components are grouped into generations, for example PowerEdge 14th generation servers, 15th generation, or 16th generation. This article provides general guidance for PowerEdge server model naming convention to identify the generation and common components. This article also lists all PowerEdge servers by model including type, CPU, generation, and remote management components. View Less

"Dell PowerEdge Servers by Generation[5]," 1.

[3] Available at https://www.dell.com/support/kbdoc/en-us/000128635/dell-servers-what-are-the-raid-levels-and-their-specifications?lang=en.

[4] Available at https://www.dell.com/support/kbdoc/en-us/000178190/dell-poweredge-how-to-assign-a-hard-drive-in-global-hot-spare.

[5] Available at https://www.dell.com/support/kbdoc/en-us/000137343/how-to-identify-which-generation-your-dell-poweredge-server-belongs-to.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Rack Models			
	R360	R250	R240
	R660	R350	R340
	R660xs	R450	R440
	R6615	R550	R540
	R6625	R650	R640
	R760	R650xs	R6415
	R760xa	R6515	R740
	R760xd2	R6525	R740xd
	R760xs	R750	R740xd2
	R7615	R750xa	R7415
	R7625	R750xs	R7425
	R860	R7515	R840
	R960	R7525	R940
			R940xa

"Dell PowerEdge Servers by Generation," 2.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]				
	R240	Compute	Intel	14	iDRAC9
	R250	Compute	Intel	15	iDRAC9
	R300	Compute	Intel	10	DRAC5
	R310	Compute	Intel	11	iDRAC6 Monolithic
	R320	Compute	Intel	12	iDRAC7
	R330	Compute	Intel	13	iDRAC8
	R340	Compute	Intel	14	iDRAC9
	R350	Compute	Intel	15	iDRAC9
	R360	Compute	Intel	16	iDRAC9
	R410	Compute	Intel	11	iDRAC6 Monolithic
	R415	Compute	AMD	11	iDRAC6 Monolithic
	R420	Compute	Intel	12	iDRAC7
	R420xr	Compute	Intel	12	iDRAC7
	"Dell PowerEdge Servers by Generation," 8.				

Claim 13

Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

PowerEdge Model	Type	CPU Vendor	Generation	Dell Remote Management
R430	Compute	Intel	13	iDRAC8
R440	Compute	Intel	14	iDRAC9
R450	Compute	Intel	15	iDRAC9
R510	Compute	Intel	11	iDRAC6 Monolithic
R515	Compute	AMD	11	iDRAC6 Monolithic
R520	Compute	Intel	12	iDRAC7
R530	Compute	Intel	13	iDRAC8
R530xd	Compute	Intel	13	iDRAC8
R540	Compute	Intel	14	iDRAC9
R550	Compute	Intel	15	iDRAC9
R610	Compute	Intel	11	iDRAC6 Monolithic
R620	Compute	Intel	12	iDRAC7

Contact Support

"Dell PowerEdge Servers by Generation," 9.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

R630	Compute	Intel	13	iDRAC8
R640	Compute	Intel	14	iDRAC9
R6415	Compute	AMD	14	iDRAC9
R650	Compute	Intel	15	iDRAC9
R650xs	Compute	Intel	15	iDRAC9
R6515	Compute	AMD	15	iDRAC9
R6525	Compute	AMD	15	iDRAC9
R660	Compute	Intel	16	iDRAC9
R660xs	Compute	Intel	16	iDRAC9
R6615	Compute	AMD	16	iDRAC9
R6625	Compute	AMD	16	iDRAC9
R710	Compute	Intel	11	iDRAC6 Monolithic
R715	Compute	AMD	11	iDRAC6 Monolithic

"Dell PowerEdge Servers by Generation," 9.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

PowerEdge Model	Type	CPU Vendor	Generation	Dell Remote Management
R720	Compute	Intel	12	iDRAC7
R720xd	Compute	Intel	12	iDRAC7
R730	Compute	Intel	13	iDRAC8
R730xd	Compute	Intel	13	iDRAC8
R740	Compute	Intel	14	iDRAC9
R740xd	Compute	Intel	14	iDRAC9
R740xd2	Compute	Intel	14	iDRAC9
R7415	Compute	AMD	14	iDRAC9
R7425	Compute	AMD	14	iDRAC9
R750	Compute	Intel	15	iDRAC9
R750xa	Compute	Intel	15	iDRAC9
R750xs	Compute	Intel	15	iDRAC9

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"Dell PowerEdge Servers by Generation," 10.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

R7515	Compute	AMD	15	iDRAC9
R7525	Compute	AMD	15	iDRAC9
R760	Compute	Intel	16	iDRAC9
R760xa	Compute	Intel	16	iDRAC9
R760xd2	Compute	Intel	16	iDRAC9
R760xs	Compute	Intel	16	iDRAC9
R7615	Compute	AMD	16	iDRAC9
R7625	Compute	AMD	16	iDRAC9
R805	Compute	AMD	10	DRAC5
R810	Compute	Intel	11	iDRAC6 Monolithic
R815	Compute	AMD	11	iDRAC6 Monolithic
R820	Compute	Intel	12	iDRAC7
R830	Compute	Intel	13	iDRAC8

"Dell PowerEdge Servers by Generation," 10.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

PowerEdge Model	Type	CPU Vendor	Generation	Dell Remote Management
R840	Compute	Intel	14	iDRAC9
R860	Compute	Intel	16	iDRAC9
R900	Compute	Intel	10	DRAC5
R905	Compute	AMD	10	DRAC5
R910	Compute	Intel	11	iDRAC6 Monolithic
R920	Compute	Intel	12	iDRAC7
R930	Compute	Intel	13	iDRAC8
R940	Compute	Intel	14	iDRAC9
R940xa	Compute	Intel	14	iDRAC9
R960	Compute	Intel	16	iDRAC9

Contact Support

"Dell PowerEdge Servers by Generation," 11.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Understanding RAID concepts

Storage Management uses the Redundant Array of Independent Disks (RAID) technology to provide Storage Management capability. Understanding Storage Management requires an understanding of RAID concepts, as well as some familiarity with how the RAID controllers and operating system view disk space on your system.

What is RAID

RAID is a technology for managing the storage of data on the physical disks that reside or are attached to the system. A key aspect of RAID is the ability to span physical disks so that the combined storage capacity of multiple physical disks can be treated as a single, extended disk space. Another key aspect of RAID is the ability to maintain redundant data which can be used to restore data in the event of a disk failure. RAID uses different techniques, such as striping, mirroring, and parity, to store and reconstruct data. There are different RAID levels that use different methods for storing and reconstructing data. The RAID levels have different characteristics in terms of read/write performance, data protection, and storage capacity. Not all RAID levels maintain redundant data, which means for some RAID levels lost data cannot be restored. The RAID level you choose depends on whether your priority is performance, protection, or storage capacity.

NOTE: The RAID Advisory Board (RAB) defines the specifications used to implement RAID. Although RAB defines the RAID levels, commercial implementation of RAID levels by different vendors may vary from the actual RAID specifications. An implementation of a particular vendor may affect the read and write performance and the degree of data redundancy.

Hardware and software RAID

RAID can be implemented with either hardware or software. A system using hardware RAID has a RAID controller that implements the RAID levels and processes data reads and writes to the physical disks. When using software RAID provided by the operating system, the operating system implements the RAID levels. For this reason, using software RAID by itself can slow the system performance. You can, however, use software RAID along with hardware RAID volumes to provide better performance and variety in the configuration of RAID volumes. For example, you can mirror a pair of hardware RAID 5 volumes across two RAID controllers to provide RAID controller redundancy.

Integrated Dell Remote Access Controller 9 User's Guide[6], 226.

[6] Available at https://dl.dell.com/content/manual71585839-integrated-dell-remote-access-controller-9-user-s-guide.pdf?language=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

RAID concepts

RAID uses particular techniques for writing data to disks. These techniques enable RAID to provide data redundancy or better performance. These techniques include:

- Mirroring — Duplicating data from one physical disk to another physical disk. Mirroring provides data redundancy by maintaining two copies of the same data on different physical disks. If one of the disks in the mirror fails, the system can continue to operate using the unaffected disk. Both sides of the mirror contain the same data always. Either side of the mirror can act as the operational side. A mirrored RAID disk group is comparable in performance to a RAID 5 disk group in read operations but faster in write operations.
- Striping — Disk striping writes data across all physical disks in a virtual disk. Each stripe consists of consecutive virtual disk data addresses that are mapped in fixed-size units to each physical disk in the virtual disk using a sequential pattern. For example, if the virtual disk includes five physical disks, the stripe writes data to physical disks one through five without repeating any of the physical disks. The amount of space consumed by a stripe is the same on each physical disk. The portion of a stripe that resides on a physical disk is a stripe element. Striping by itself does not provide data redundancy. Striping in combination with parity does provide data redundancy.
- Stripe size — The total disk space consumed by a stripe not including a parity disk. For example, consider a stripe that contains 64KB of disk space and has 16KB of data residing on each disk in the stripe. In this case, the stripe size is 64KB and the stripe element size is 16KB.
- Stripe element — A stripe element is the portion of a stripe that resides on a single physical disk.
- Stripe element size — The amount of disk space consumed by a stripe element. For example, consider a stripe that contains 64KB of disk space and has 16KB of data residing on each disk in the stripe. In this case, the stripe element size is 16KB and the stripe size is 64KB.
- Parity — Parity refers to redundant data that is maintained using an algorithm in combination with striping. When one of the striped disks fails, the data can be reconstructed from the parity information using the algorithm.
- Span — A span is a RAID technique used to combine storage space from groups of physical disks into a RAID 10, 50, or 60 virtual disk.

Integrated Dell Remote Access Controller 9 User's Guide, 226-227.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

RAID levels

Each RAID level uses some combination of mirroring, striping, and parity to provide data redundancy or improved read and write performance. For specific information on each RAID level, see Choosing raid levels.

Organizing data storage for availability and performance

RAID provides different methods or RAID levels for organizing the disk storage. Some RAID levels maintain redundant data so that you can restore data after a disk failure. Different RAID levels also entail an increase or decrease in the I/O (read and write) performance of a system.

Maintaining redundant data requires the use of additional physical disks. The possibility of a disk failure increases with an increase in the number of disks. Since the differences in I/O performance and redundancy, one RAID level may be more appropriate than another based on the applications in the operating environment and the nature of the data being stored.

When choosing a RAID level, the following performance and cost considerations apply:

- **Availability or fault-tolerance** — Availability or fault-tolerance refers to the ability of a system to maintain operations and provide access to data even when one of its components has failed. In RAID volumes, availability or fault-tolerance is achieved by maintaining redundant data. Redundant data includes mirrors (duplicate data) and parity information (reconstructing data using an algorithm).
- **Performance** — Read and write performance can be increased or decreased depending on the RAID level you choose. Some RAID levels may be more appropriate for particular applications.
- **Cost efficiency** — Maintaining the redundant data or parity information associated with RAID volumes requires additional disk space. In situations where the data is temporary, easily reproduced, or non-essential, the increased cost of data redundancy may not be justified.
- **Mean Time Between Failure (MTBF)** — Using additional disks to maintain data redundancy also increases the chance of disk failure at any given moment. Although this option cannot be avoided in situations where redundant data is a requirement, it does have implications on the workload of the system support staff within your organization.
- **Volume** — Volume refers to a single disk non-RAID virtual disk. You can create volumes using external utilities like the O-ROM <Ctrl> <r>. Storage Management does not support the creation of volumes. However, you can view volumes and use drives from these volumes for creation of new virtual disks or Online Capacity Expansion (OCE) of existing virtual disks, provided free space is available.

Integrated Dell Remote Access Controller 9 User's Guide, 227.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
	The iDRAC interfaces support the following PERC11 controllers: • PERC H350 Adapter • PERC H355 Front • PERC H355 Adapter • PERC H750 Adapter • PERC H755 Adapter • PERC H755 Front • PERC H755N Front • PERC H755 MX The iDRAC interfaces support the following PERC10 controllers: • PERC H345 Front • PERC H345 Adapter • PERC H740P Mini • PERC H740P Adapter • PERC H745 Front • PERC H745 Adapter • PERC H840 Adapter • PERC H745P MX Integrated Dell Remote Access Controller 9 User's Guide, 234.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Storage controller specifications

The PowerEdge R860 system supports the following controller cards:

Table 18. Storage controller cards

Supported storage controller cards
Internal controllers • PERC H965i • PERC H755 • PERC H355
External controllers • PERC H965e • HBA355e
Internal Boot • Boot Optimized Storage Subsystem (BOSS-N1): HWRAID 2 x M.2 NVMe SSD • USB
Software RAID • S160
SAS Host Bus Adapters (HBA) • HBA355i

R860 Installation and Service Manual[7], 9.

Working with the Dell PowerEdge RAID controllers	For information about understanding the features of the Dell PowerEdge RAID controllers (PERC), Software RAID controllers, or BOSS card and deploying the cards, see the Storage controller documentation.	www.dell.com/storagecontrollermanuals

[7] Available at https://dl.dell.com/content/manual30976811-dell-poweredge-r860-installation-and-service-manual.pdf?language=en-us (dated March 2024).

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
	R940 Installation and Service Manual[8], 25. PERC H840 RAID Adapter for External MD14XX Only, 8GB NV Cache, Low Profile/Full Height, Customer Install ★★★★★ 4.2 (10)  Power Edge Raid Controller ("PERC") H840 Information Page[9], 4.

[8] Available at https://dl.dell.com/content/manual30976811-dell-poweredge-r860-installation-and-service-manual.pdf?language=en-us (dated March 2024).

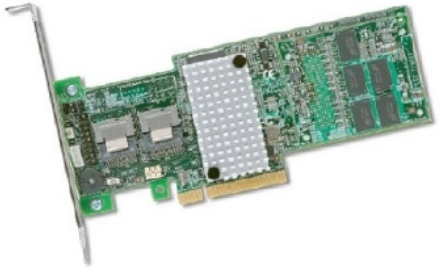
[9] Available at https://www.dell.com/en-us/shop/perc-h840-raid-adapter-for-external-md14xx-only-8gb-nv-cache-low-profile-full-height-customer-install/apd/405-aamz/storage-drives-media#support_section.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

PERC H840 RAID Adapter for External MD14XX Only, 8GB NV Cache, Low Profile/Full Height, Customer Install

Dell Part 405-AAMZ

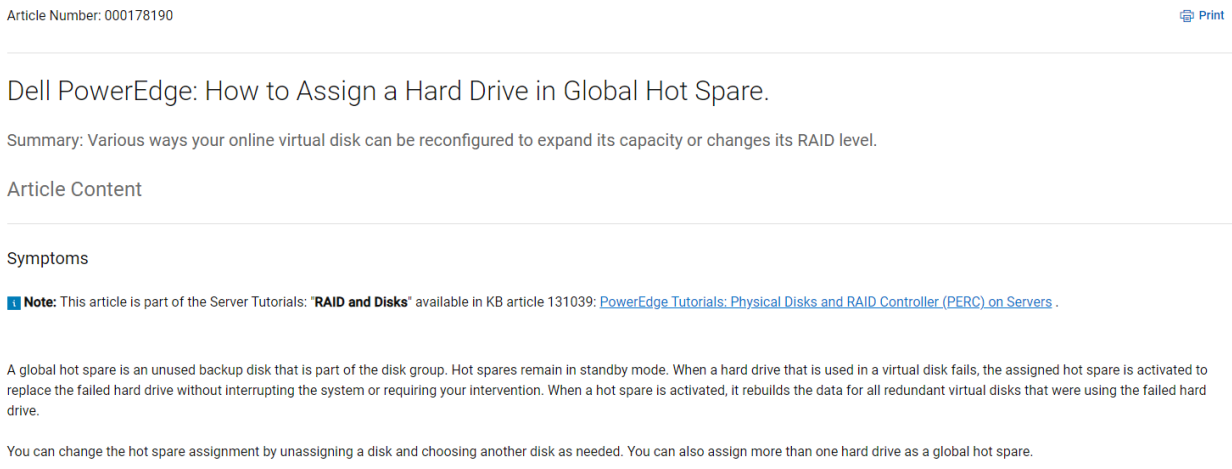
The PERC H840 RAID Controller from Dell offers reliability and performance in addition to providing management with the tolerant disk subsystem failures. This RAID controller offers expandable 4 GB storage capacity to improve the performance of your server systems. The double module channel provides high-speed connectivity. This product has been tested and validated on Dell systems to ensure compatibility with your computer. It is supported by Dell Technical Support when used with a Dell system.



Power Edge Raid Controller ("PERC") H840 Information Page, 5.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
	 Power Edge Raid Controller ("PERC") H840 Information Page, 8.
[a] backing up data in a disk array including a plurality of disk drives onto a backup storage device; and	The Exemplary Dell '544 Products back up data in a disk array including a plurality of disk drives onto a backup storage device. *See, e.g.,*:

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]



Article Number: 000178190

Print

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You can change the hot spare assignment by unassigning a disk and choosing another disk as needed. You can also assign more than one hard drive as a global hot spare.

"Dell PowerEdge: How to Assign a Hard Drive in Global Hot Spare," 1.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Table 1. Specifications for PERC S160

Specification	PERC S160
SATA SSD technology	Yes
NVMe support	Yes
SAS connectors	No
Dell-compliant SAS compatibility	No
Direct-connected end devices	Dell-compliant HDDs, SSDs, and SATA DVDs
SMART error support through management applications	Yes
Backplane supported systems	Yes
Support for internal tape drive	No
Support for global hot spare	Yes
Support for 512 native and 512e drives	Yes
Support for 4Kn native drives	No
Maximum number of global hot spares	Varies with the number of free disks in the system
Maximum number of physical disks supported (SATA + NVMe)	30
Minimum RAM size required	16 GB

S160 User's Guide, 6.

Supported PowerEdge servers

The following PowerEdge servers support the S160 controller:

- PowerEdge R6615
- PowerEdge R7615
- PowerEdge R6625
- PowerEdge R7625
- PowerEdge R660
- PowerEdge R760

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
	S160 User's Guide, 9. **Mirror rebuilding** A RAID mirror configuration can be rebuilt after a new physical disk is inserted and the physical disk is designated as a hot spare. NOTE: The system does not have to be rebooted. **Fault tolerance** The following fault tolerance features are available with the PERC S160: • Physical disk failure detection (automatic). • Virtual disk rebuild using hot spares (automatic, if the hot spare is configured for this feature). • Parity generation and checking (RAID 5 only). • Hot-swap manual replacement of a physical disk without rebooting the system (only for systems with a backplane that allows hot-swapping). If one side of a RAID 1 (mirror) fails, data can be rebuilt by using the physical disk on the other side of the mirror. If a physical disk in RAID 5 fails, parity data exists on the remaining physical disks, which can be used to restore the data to a new replacement physical disk configured as a hot spare. If a physical disk fails in RAID 10, the virtual disk remains functional and data is read from the surviving mirrored physical disk(s). A single disk failure in each mirrored set can be sustained, depending on how the mirrored set fails. S160 User's Guide, 12.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Managing the hot spare disks

Manage Hot Spare(s) screen enables you to assign or unassign a global or dedicated hot spare(s).

1. Enter the BIOS Configuration Utility. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, use the arrow keys to select **Manage Hot Spare(s)** and press <Enter>.
   The **Manage Hot Spare(s)** screen display:
   - global hot spare disks
   - dedicated hot spare disks

Assigning the global hot spare disks

A global hot spare disk is a backup physical disk that can be used by any redundant virtual disk. It is not assigned (dedicated) to any specific virtual disk. Virtual disks can typically be rebuilt by using a global spare disk, as long as the global hot spare is not already part of the virtual disk and has enough available capacity. Unlike a dedicated hot spare, a global hot spare can be assigned at anytime, even while tasks are running on virtual disks.

NOTE: A hot spare can be created only if a physical disk is in the **Ready** or **Normal** state in the **Physical Disks** field. If the physical disk is in the **Online** state, the disk is being used by a virtual disk and cannot be selected as a hot spare.

NOTE: If disk space is available in the global hot spare drive then a single global hot spare can be assigned as a hot spare to multiple degraded virtual drives. Therefore, it is possible for the same global hot spare to become part of different degraded virtual drives that have different RAID levels.

Perform the following procedure to assign a global hot spare disk:

1. Enter the **BIOS Configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press <Enter>.
3. Select **Assign Global Hot Spare(s)**. Press <Enter>.
4. Use the up or down arrow key to select a physical disk(s) to be used as a global hot spare(s). Press <Insert>.
5. Press <Enter> to add the global hot spare.
6. Press the <C> key to confirm the action.

Unassign hot spare disks

1. Enter the **BIOS Configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press Enter.
3. Select **Unassign Hot Spare**. Press Enter.
4. Use the up or down arrow key to select the physical disk to delete as a hot spare.
5. Press Insert. To delete the hot spare, press Enter
6. Press the C key to confirm the action.

<table>
<tr><th>Claim 13</th><th>Exemplary Dell ’544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]</th></tr>
<tr><td></td><td>S160 User’s Guide, 21.

Table 13. View Physical Disk Properties (continued)
<table><tr><th>Menu Item</th><th>Description</th></tr><tr><td>Size</td><td>Displays the total storage space of the physical disk.</td></tr><tr><td>SMART status</td><td>Displays if the SMART feature is enabled or disabled for the physical disk.</td></tr><tr><td>Revision</td><td>Displays the revision.</td></tr><tr><td>Device Type</td><td>Displays the device type.</td></tr><tr><td>Certified (SATA Drives only)</td><td>Displays if the physical disk is Dell certified or not.</td></tr><tr><td>Connector Port (SATA Drives only)</td><td>Displays the port number in which the SATA physical disk is installed.</td></tr><tr><td>Disk Write Cache (SATA Drives only)</td><td>Displays if the disk cache is enabled or disabled.</td></tr><tr><td>Hot Spare</td><td>Displays if the physical disk is assigned as a hot spare.</td></tr></table>
S160 User’s Guide, 30.</td></tr>
</table>

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

NOTE: Ensure that you change the physical disk write cache policy of a global hot spare disk after rebuild to the write cache policy of the last configured virtual disk.

NOTE: In the **View Virtual Disk Properties** screen, ensure that the physical disk write cache setting is consistent across the physical disk associated with the virtual disk.

NOTE: If you have Linux RAID configured on the system, you cannot modify the physical disk write cache policy feature settings.

NOTE: For more information about the physical disk write cache behavior, see the Troubleshooting your system section.

Assigning the global hot spare

1. Enter the **Dell PERC S160 Configuration Utility**. See Entering the DELL PERC S160 Configuration Utility .
2. Click **Physical Disk Management** > **Select Physical Disk Operations**.
3. Select the physical disk that is in the ready state from the drop-down menu.
4. Click the link **Assign Global Hot Spares.**

NOTE: A global hot spare disk cannot be created if you have Linux RAID configured on the system.

Unassign a global hot spare

NOTE: Unassigning a hotspare may place the data at risk in the event of a disk failure.

1. Enter the **Dell PERC S160 Configuration Utility**. See Entering the DELL PERC S160 Configuration Utility.
2. Click **Physical Disk Management** > **Select Physical Disk Operations**.
3. Select a global hot spare disk from the drop-down menu.
4. Click the link **Unassign Hot Spare**.
   Confirmation screen appears.
5. Click **Yes** to confirm.

Assigning the dedicated hot spare

WARNING: Assigning a disk as a hot spare will cause the data on the disk to be permanently deleted.

NOTE: After a hot spare rebuild, creating new partial virtual disk on the same Linux RAID disk is not supported.

1. Enter the **Dell PERC S160 Configuration Utility**. See Entering the DELL PERC S160 Configuration Utility.
2. Click **Virtual Disk Management** > **Manage Virtual Disk Properties**.
3. Select the virtual disk that is in the ready state from the drop-down menu.
4. Click **Manage Dedicated Hot Spares**
5. Select the physical disk that you want to be assigned as a dedicated hot-spare disk.
6. Click the link **Add Hot Spare Disk**.

S160 User's Guide, 31.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Viewing global hot spares

The View Global Hot Spares screen displays the physical disk assigned as global hot spare.

In the **System Setup Main Menu**, click **Device Settings** > **Dell PERC S160 Configuration Utility** > **Physical Disk Management** > **View Global Hot Spares**

S160 User's Guide, 32.

Rebuilding a virtual disk the global hot spare is not listed as online in HII or iDRAC

Description:	After the rebuild of a virtual disk is completed using the global hot spare the status of the disk is not listed as online, instead the status of the disk is listed as ready.
Solution	This is an expected behavior. No action is required.

S160 User's Guide, 44.

<table>
<tr><th>Claim 13</th><th>Exemplary Dell ’544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]</th></tr>
<tr><td></td><td>

Table 1. Specifications for PERC S150

Specification	PERC S150
SATA SSD technology	Yes
NVMe support	Yes
SAS connectors	No
Dell-compliant SAS compatibility	No
Direct-connected end devices	Dell-compliant HDDs, SSDs, and SATA DVDs
SMART error support through management applications	Yes
Backplane supported systems	Yes
Support for internal tape drive	No
Support for global hot spare	Yes
Support for 512 native and 512e drives	Yes
Support for 4Kn native drives	No
Maximum number of global hot spares	Varies with the number of free disks in the system
Maximum number of physical disks supported (SATA + NVMe)	30
Minimum RAM size required	16 GB

S150 User’s Guide[10], 6.
</td></tr>
</table>

[10] Available at https://dl.dell.com/content/manual26808573-dell-poweredge-raid-controller-s150-user-s-guide.pdf?language=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Supported PowerEdge systems

The following PowerEdge systems support the S150 controller:

- PowerEdge R6515
- PowerEdge R7515
- PowerEdge R6525
- PowerEdge R7525
- PowerEdge C6525
- PowerEdge R650
- PowerEdge R650 XS
- PowerEdge R750
- PowerEdge R750 XS
- PowerEdge R750 XA
- PowerEdge MX750C
- PowerEdge C6520
- PowerEdge R450
- PowerEdge R550
- PowerEdge XR11
- PowerEdge XR12
- PowerEdge XE8545
- PowerEdge T150
- PowerEdge T350
- PowerEdge R250
- PowerEdge R350

S150 User's Guide, 9.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Mirror rebuilding

A RAID mirror configuration can be rebuilt after a new physical disk is inserted and the physical disk is designated as a hot spare.

NOTE: The system does not have to be rebooted.

Fault tolerance

The following fault tolerance features are available with the PERC S150:

- Physical disk failure detection (automatic).
- Virtual disk rebuild using hot spares (automatic, if the hot spare is configured for this feature).
- Parity generation and checking (RAID 5 only).
- Hot-swap manual replacement of a physical disk without rebooting the system (only for systems with a backplane that allows hot-swapping).

If one side of a RAID 1 (mirror) fails, data can be rebuilt by using the physical disk on the other side of the mirror.

If a physical disk in RAID 5 fails, parity data exists on the remaining physical disks, which can be used to restore the data to a new replacement physical disk configured as a hot spare.

If a physical disk fails in RAID 10, the virtual disk remains functional and data is read from the surviving mirrored physical disk(s). A single disk failure in each mirrored set can be sustained, depending on how the mirrored set fails.

S150 User's Guide, 12.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Managing the hot spare disks

Manage Hot Spare(s) screen enables you to assign or unassign a global or dedicated hot spare(s).

1. Enter the BIOS Configuration Utility. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, use the arrow keys to select **Manage Hot Spare(s)** and press <Enter>.
   The **Manage Hot Spare(s)** screen display:
   - global hot spare disks
   - dedicated hot spare disks

Assigning the global hot spare disks

A global hot spare disk is a backup physical disk that can be used by any redundant virtual disk. It is not assigned (dedicated) to any specific virtual disk. Virtual disks can typically be rebuilt by using a global spare disk, as long as the global hot spare is not already part of the virtual disk and has enough available capacity. Unlike a dedicated hot spare, a global hot spare can be assigned at anytime, even while tasks are running on virtual disks.

NOTE: A hot spare can be created only if a physical disk is in the **Ready** or **Normal** state in the **Physical Disks** field. If the physical disk is in the **Online** state, the disk is being used by a virtual disk and cannot be selected as a hot spare.

NOTE: If disk space is available in the global hot spare drive then a single global hot spare can be assigned as a hot spare to multiple degraded virtual drives. Therefore, it is possible for the same global hot spare to become part of different degraded virtual drives that have different RAID levels.

Perform the following procedure to assign a global hot spare disk:

1. Enter the **BIOS Configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press <Enter>.
3. Select **Assign Global Hot Spare(s)**. Press <Enter>.
4. Use the up or down arrow key to select a physical disk(s) to be used as a global hot spare(s). Press <Insert>.
5. Press <Enter> to add the global hot spare.
6. Press the <C> key to confirm the action.

Unassign hot spare disks

1. Enter the **BIOS Configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press Enter.
3. Select **Unassign Hot Spare**. Press Enter.
4. Use the up or down arrow key to select the physical disk to delete as a hot spare.
5. Press Insert. To delete the hot spare, press Enter
6. Press the C key to confirm the action.

S150 User's Guide, 26.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
	Assigning the global hot spare 1. Enter the **Dell PERC S150 Configuration Utility**. See Entering the DELL PERC S150 Configuration Utility . 2. Click **Physical Disk Management** > **Select Physical Disk Operations**. 3. Select the physical disk that is in the ready state from the drop-down menu. 4. Click the link **Assign Global Hot Spares.** **NOTE:** A global hot spare disk cannot be created if you have Linux RAID configured on the system. S150 User's Guide, 37.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Unassign a global hot spare

NOTE: Unassigning a hotspare may place the data at risk in the event of a disk failure.

1. Enter the **Dell PERC S160 Configuration Utility**. See Entering the DELL PERC S160 Configuration Utility.
2. Click **Physical Disk Management** > **Select Physical Disk Operations**.
3. Select a global hot spare disk from the drop-down menu.
4. Click the link **Unassign Hot Spare**.
   Confirmation screen appears.
5. Click **Yes** to confirm.

Assigning the dedicated hot spare

WARNING: Assigning a disk as a hot spare will cause the data on the disk to be permanently deleted.

NOTE: After a hot spare rebuild, creating new partial virtual disk on the same Linux RAID disk is not supported.

1. Enter the **Dell PERC S150 Configuration Utility**. See Entering the DELL PERC S150 Configuration Utility.
2. Click **Virtual Disk Management** > **Manage Virtual Disk Properties**.
3. Select the virtual disk that is in the ready state from the drop-down menu.
4. Click **Manage Dedicated Hot Spares**
5. Select the physical disk that you want to be assigned as a dedicated hot-spare disk.
6. Click the link **Add Hot Spare Disk**.
   Confirmation screen appears.
7. Select **Confirm** and click **YES** to complete the dedicated hot spare disk assignment.

S150 User's Guide, 38.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Supported PowerEdge systems

The following PowerEdge systems support the S140 controller:

- PowerEdge C6400
- PowerEdge C6420
- PowerEdge C4140
- PowerEdge FC640
- PowerEdge M640
- PowerEdge MX7000
- PowerEdge MX740c
- PowerEdge MX840c
- PowerEdge R240
- PowerEdge R340
- PowerEdge R440
- PowerEdge R540
- PowerEdge R640
- PowerEdge R740
- PowerEdge R740xd
- PowerEdge R740xd2
- PowerEdge R840
- PowerEdge R940
- PowerEdge R940xa
- PowerEdge R6415
- PowerEdge R7425
- PowerEdge R7415

S140 User's Guide, "Supported PowerEdge systems"[11], 1.

[11] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/supported-poweredge-systems?guid=guid-875adb5f-9d57-4e2b-a57c-43e4dca3b283&lang=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Mirror rebuilding

A RAID mirror configuration can be rebuilt after a new physical disk is inserted and the physical disk is designated as a hot spare.

S140 User's Guide, "Mirror Rebuilding"[12], 1.

Dell PowerEdge RAID Controller S140 User's Guide

Fault tolerance

The following fault tolerance features are available with the PERC S140: If one side of a RAID 1 (mirror) fails, data can be rebuilt by using the physical disk on the other side of the mirror.

- Physical disk failure detection (automatic).
- Virtual disk rebuild using hot spares (automatic, if the hot spare is configured for this feature).
- Parity generation and checking (RAID 5 only).
- Hot-swap manual replacement of a physical disk without rebooting the system (only for systems with a backplane that allows hot-swapping).

If a physical disk in RAID 5 fails, parity data exists on the remaining physical disks, which can be used to restore the data to a new replacement physical disk configured as a hot spare.

If a physical disk fails in RAID 10, the virtual disk remains functional and data is read from the surviving mirrored physical disk(s). A single disk failure in each mirrored set can be sustained, depending on how the mirrored set fails.

S140 User's Guide, "Fault Tolerance"[13], 1.

[12] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/mirror-rebuilding?guid=guid-ee4012fa-6518-4cb5-b629-d54143d04b16&lang=en-us.

[13] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/fault-tolerance?guid=guid-0e22affd-cdd9-47c1-9053-87200db1c9e6&lang=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
	Managing the hot spare disks **Manage Hot Spare(s)** screen enables you to assign or unassign a global or dedicated hot spare(s). 1. Enter the BIOS Configuration Utility. See Entering the BIOS configuration utility. 2. In the **Main Menu** screen, use the arrow keys to select **Manage Hot Spare(s)** and press <Enter>. The **Manage Hot Spare(s)** screen display: ◦ global hot spare disks ◦ dedicated hot spare disks Assigning the global hot spare disks Assigning the dedicated hot spare disks Unassign hot spare disks S140 User's Guide, "Managing the Hot Spare Disks"[14], 1.

[14] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/managing-the-hot-spare-disks?guid=guid-54fee40d-0abb-4314-a417-b64fb7a23ee4&lang=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Assigning the global hot spare disks

A global hot spare disk is a backup physical disk that can be used by any redundant virtual disk. It is not assigned (dedicated) to any specific virtual disk. Virtual disks can typically be rebuilt by using a global spare disk, as long as the global hot spare is not already part of the virtual disk and has enough available capacity. Unlike a dedicated hot spare, a global hot spare can be assigned at anytime, even while tasks are running on virtual disks.

NOTE:A hot spare can be created only if a physical disk is in the **Ready** or **Normal** state in the **Physical Disks** field. If the physical disk is in the **Online** state, the disk is being used by a virtual disk and cannot be selected as a hot spare.

NOTE:If disk space is available in the global hot spare drive then a single global hot spare can be assigned as a hot spare to multiple degraded virtual drives. Therefore, it is possible for the same global hot spare to become part of different degraded virtual drives that have different RAID levels.

Perform the following procedure to assign a global hot spare disk:

1. Enter the **BIOS Configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press <Enter>.
3. Select **Assign Global Hot Spare(s)**. Press <Enter>.
4. Use the up or down arrow key to select a physical disk(s) to be used as a global hot spare(s). Press <Insert>.
5. Press <Enter> to add the global hot spare.
6. Press the <C> key to confirm the action.

S140 User's Guide, "Assigning Global Hot Spare Disks"[15], 1.

[15] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/assigning-the-global-hot-spare-disks?guid=guid-c2597f02-9418-491a-9bbc-327188e0bb32&lang=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Assigning the dedicated hot spare disks

A dedicated hot spare is a backup physical disk for the redundant virtual disk to which it is assigned. The physical disk that is used as a dedicated hot spare cannot be a member of an existing virtual disk. When the hot spare is activated, it becomes the receptacle for the data from the failed physical disk member of the volume, without interrupting the system or requiring your intervention. A dedicated hot spare can be assigned to any redundant virtual disk, and up to four hot spares can be assigned to a virtual disk. A dedicated hot spare cannot be assigned while a task is running on the virtual disk.

NOTE:A virtual disk is marked **Failed** or **Degraded** if a physical disk reports a **Failed** state, or if the SAS/SATA cable to the physical disk or power cable is disconnected.

NOTE: If a virtual disk with an assigned dedicated hot spare is deleted, the dedicated hot spare is also deleted and the physical disk state changes to the **Ready state**.

Perform the following procedure to assign a dedicated hot spare disk:

1. Enter the **BIOS configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press Enter.
3. Select **Assign Dedicated Hot Spare**. Press Enter.
4. Use the up or down arrow key to select a physical disk for use as a dedicated hot spare and press Insert.
5. Press Enter to add the dedicated hot spare.
6. Press the C key to confirm the action.

S140 User's Guide, "Assigning Dedicated Hot Spare Disks"[16], 1.

[16] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/assigning-the-dedicated-hot-spare-disks?guid=guid-c0d57367-6135-411b-abf5-a7fd2bb3a6b3&lang=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Understanding RAID concepts

Storage Management uses the Redundant Array of Independent Disks (RAID) technology to provide Storage Management capability. Understanding Storage Management requires an understanding of RAID concepts, as well as some familiarity with how the RAID controllers and operating system view disk space on your system.

What is RAID

RAID is a technology for managing the storage of data on the physical disks that reside or are attached to the system. A key aspect of RAID is the ability to span physical disks so that the combined storage capacity of multiple physical disks can be treated as a single, extended disk space. Another key aspect of RAID is the ability to maintain redundant data which can be used to restore data in the event of a disk failure. RAID uses different techniques, such as striping, mirroring, and parity, to store and reconstruct data. There are different RAID levels that use different methods for storing and reconstructing data. The RAID levels have different characteristics in terms of read/write performance, data protection, and storage capacity. Not all RAID levels maintain redundant data, which means for some RAID levels lost data cannot be restored. The RAID level you choose depends on whether your priority is performance, protection, or storage capacity.

NOTE: The RAID Advisory Board (RAB) defines the specifications used to implement RAID. Although RAB defines the RAID levels, commercial implementation of RAID levels by different vendors may vary from the actual RAID specifications. An implementation of a particular vendor may affect the read and write performance and the degree of data redundancy.

Hardware and software RAID

RAID can be implemented with either hardware or software. A system using hardware RAID has a RAID controller that implements the RAID levels and processes data reads and writes to the physical disks. When using software RAID provided by the operating system, the operating system implements the RAID levels. For this reason, using software RAID by itself can slow the system performance. You can, however, use software RAID along with hardware RAID volumes to provide better performance and variety in the configuration of RAID volumes. For example, you can mirror a pair of hardware RAID 5 volumes across two RAID controllers to provide RAID controller redundancy.

Integrated Dell Remote Access Controller 9 User's Guide, 226.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

RAID concepts

RAID uses particular techniques for writing data to disks. These techniques enable RAID to provide data redundancy or better performance. These techniques include:

- Mirroring — Duplicating data from one physical disk to another physical disk. Mirroring provides data redundancy by maintaining two copies of the same data on different physical disks. If one of the disks in the mirror fails, the system can continue to operate using the unaffected disk. Both sides of the mirror contain the same data always. Either side of the mirror can act as the operational side. A mirrored RAID disk group is comparable in performance to a RAID 5 disk group in read operations but faster in write operations.
- Striping — Disk striping writes data across all physical disks in a virtual disk. Each stripe consists of consecutive virtual disk data addresses that are mapped in fixed-size units to each physical disk in the virtual disk using a sequential pattern. For example, if the virtual disk includes five physical disks, the stripe writes data to physical disks one through five without repeating any of the physical disks. The amount of space consumed by a stripe is the same on each physical disk. The portion of a stripe that resides on a physical disk is a stripe element. Striping by itself does not provide data redundancy. Striping in combination with parity does provide data redundancy.
- Stripe size — The total disk space consumed by a stripe not including a parity disk. For example, consider a stripe that contains 64KB of disk space and has 16KB of data residing on each disk in the stripe. In this case, the stripe size is 64KB and the stripe element size is 16KB.
- Stripe element — A stripe element is the portion of a stripe that resides on a single physical disk.
- Stripe element size — The amount of disk space consumed by a stripe element. For example, consider a stripe that contains 64KB of disk space and has 16KB of data residing on each disk in the stripe. In this case, the stripe element size is 16KB and the stripe size is 64KB.
- Parity — Parity refers to redundant data that is maintained using an algorithm in combination with striping. When one of the striped disks fails, the data can be reconstructed from the parity information using the algorithm.
- Span — A span is a RAID technique used to combine storage space from groups of physical disks into a RAID 10, 50, or 60 virtual disk.

Integrated Dell Remote Access Controller 9 User's Guide, 226-227.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

RAID levels

Each RAID level uses some combination of mirroring, striping, and parity to provide data redundancy or improved read and write performance. For specific information on each RAID level, see Choosing raid levels.

Organizing data storage for availability and performance

RAID provides different methods or RAID levels for organizing the disk storage. Some RAID levels maintain redundant data so that you can restore data after a disk failure. Different RAID levels also entail an increase or decrease in the I/O (read and write) performance of a system.

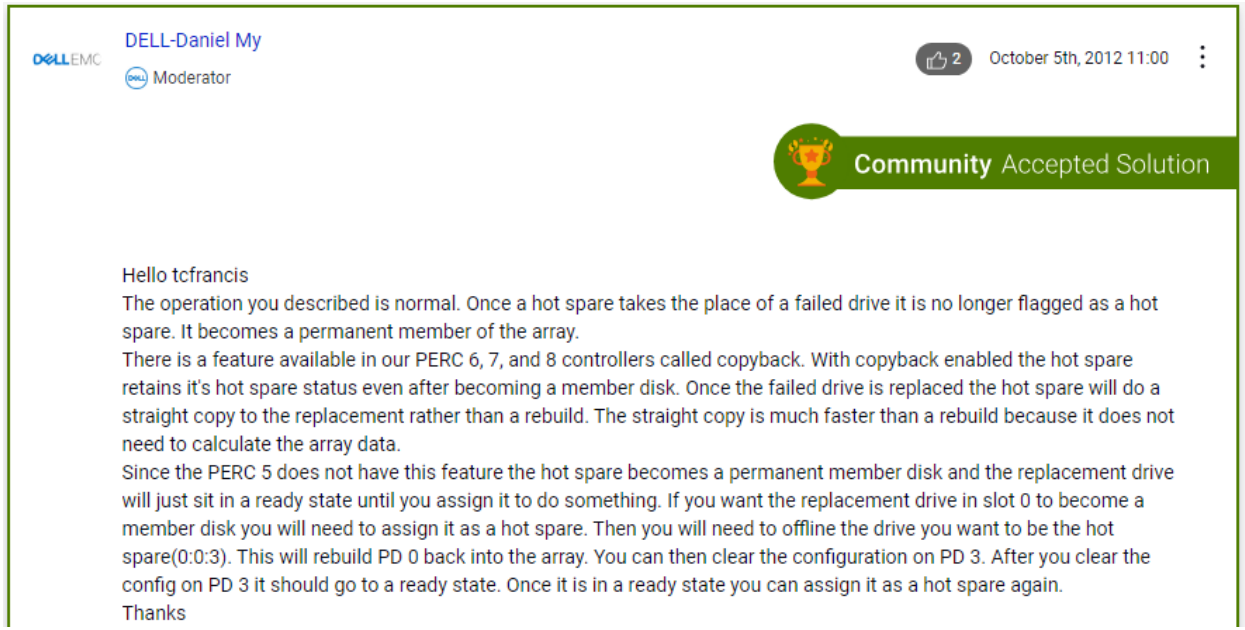
Maintaining redundant data requires the use of additional physical disks. The possibility of a disk failure increases with an increase in the number of disks. Since the differences in I/O performance and redundancy, one RAID level may be more appropriate than another based on the applications in the operating environment and the nature of the data being stored.

When choosing a RAID level, the following performance and cost considerations apply:

- **Availability or fault-tolerance** — Availability or fault-tolerance refers to the ability of a system to maintain operations and provide access to data even when one of its components has failed. In RAID volumes, availability or fault-tolerance is achieved by maintaining redundant data. Redundant data includes mirrors (duplicate data) and parity information (reconstructing data using an algorithm).
- **Performance** — Read and write performance can be increased or decreased depending on the RAID level you choose. Some RAID levels may be more appropriate for particular applications.
- **Cost efficiency** — Maintaining the redundant data or parity information associated with RAID volumes requires additional disk space. In situations where the data is temporary, easily reproduced, or non-essential, the increased cost of data redundancy may not be justified.
- **Mean Time Between Failure (MTBF)** — Using additional disks to maintain data redundancy also increases the chance of disk failure at any given moment. Although this option cannot be avoided in situations where redundant data is a requirement, it does have implications on the workload of the system support staff within your organization.
- **Volume** — Volume refers to a single disk non-RAID virtual disk. You can create volumes using external utilities like the O-ROM <Ctrl> <r>. Storage Management does not support the creation of volumes. However, you can view volumes and use drives from these volumes for creation of new virtual disks or Online Capacity Expansion (OCE) of existing virtual disks, provided free space is available.

Integrated Dell Remote Access Controller 9 User's Guide, 227.

<table>
<tr><th>Claim 13</th><th>Exemplary Dell ’544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]</th></tr>
<tr><td></td><td>
<h2>Storage controller specifications</h2>
The PowerEdge R860 system supports the following controller cards:
Table 18. Storage controller cards
<table>
<tr><th>Supported storage controller cards</th></tr>
<tr><td>Internal controllers
• PERC H965i
• PERC H755
• PERC H355</td></tr>
<tr><td>External controllers
• PERC H965e
• HBA355e</td></tr>
<tr><td>Internal Boot
• Boot Optimized Storage Subsystem (BOSS-N1): HWRAID 2 x M.2 NVMe SSD
• USB</td></tr>
<tr><td>Software RAID
• S160</td></tr>
<tr><td>SAS Host Bus Adapters (HBA)
• HBA355i</td></tr>
</table>
R860 Installation and Service Manual, 9.
<table>
<tr><td>Working with the Dell PowerEdge RAID controllers</td><td>For information about understanding the features of the Dell PowerEdge RAID controllers (PERC), Software RAID controllers, or BOSS card and deploying the cards, see the Storage controller documentation.</td><td>www.dell.com/storagecontrollermanuals</td></tr>
</table>
R940 Installation and Service Manual, 25.
</td></tr>
<tr><td>[b] when a failed disk drive among said disk drives constituting said</td><td>The Exemplary Dell ’544 Products rebuild data in said replacement disk drive from the backed-up data in the backup storage device while simultaneously providing other devices with access to the disk drives that have not failed, when a failed disk drive among said disk drives constituting said disk array is replaced with a replacement disk drive.</td></tr>
</table>

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]
disk array is replaced with a replacement disk drive, rebuilding data in said replacement disk drive from the backed-up data in the backup storage device while simultaneously providing other devices with access to the disk drives that have not failed.	*See, e.g.,*:  DELL-Daniel My Moderator 2 October 5th, 2012 11:00 Community Accepted Solution Hello tcfrancis The operation you described is normal. Once a hot spare takes the place of a failed drive it is no longer flagged as a hot spare. It becomes a permanent member of the array. There is a feature available in our PERC 6, 7, and 8 controllers called copyback. With copyback enabled the hot spare retains it's hot spare status even after becoming a member disk. Once the failed drive is replaced the hot spare will do a straight copy to the replacement rather than a rebuild. The straight copy is much faster than a rebuild because it does not need to calculate the array data. Since the PERC 5 does not have this feature the hot spare becomes a permanent member disk and the replacement drive will just sit in a ready state until you assign it to do something. If you want the replacement drive in slot 0 to become a member disk you will need to assign it as a hot spare. Then you will need to offline the drive you want to be the hot spare(0:0:3). This will rebuild PD 0 back into the array. You can then clear the configuration on PD 3. After you clear the config on PD 3 it should go to a ready state. Once it is in a ready state you can assign it as a hot spare again. Thanks Dell Community post entitled "perc 5/i returning global hot spare to hot spare after it took over for failed 0:0."[17]

[17] Available at https://www.dell.com/community/en/conversations/poweredge-hddscsiraid/perc-5i-returning-global-hot-spare-to-hot-spare-after-it-took-over-for-failed-00/647f2893f4ccf8a8ded2b656.

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Article Number: 000178190 Print

Dell PowerEdge: How to Assign a Hard Drive in Global Hot Spare.

Summary: Various ways your online virtual disk can be reconfigured to expand its capacity or changes its RAID level.

Article Content

Symptoms

Note: This article is part of the Server Tutorials: "**RAID and Disks**" available in KB article 131039: PowerEdge Tutorials: Physical Disks and RAID Controller (PERC) on Servers .

A global hot spare is an unused backup disk that is part of the disk group. Hot spares remain in standby mode. When a hard drive that is used in a virtual disk fails, the assigned hot spare is activated to replace the failed hard drive without interrupting the system or requiring your intervention. When a hot spare is activated, it rebuilds the data for all redundant virtual disks that were using the failed hard drive.

You can change the hot spare assignment by unassigning a disk and choosing another disk as needed. You can also assign more than one hard drive as a global hot spare.

"Dell PowerEdge: How to Assign a Hard Drive in Global Hot Spare," 1.

Physical disk failure detection

Physical disk failure is detected and the controller automatically rebuilds a new physical disk assigned as a hot spare.

NOTE: Refer to drive mixing restrictions for rebuilding.

S160 User's Guide, 11.

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Mirror rebuilding

A RAID mirror configuration can be rebuilt after a new physical disk is inserted and the physical disk is designated as a hot spare.

NOTE: The system does not have to be rebooted.

Fault tolerance

The following fault tolerance features are available with the PERC S160:

- Physical disk failure detection (automatic).
- Virtual disk rebuild using hot spares (automatic, if the hot spare is configured for this feature).
- Parity generation and checking (RAID 5 only).
- Hot-swap manual replacement of a physical disk without rebooting the system (only for systems with a backplane that allows hot-swapping).

If one side of a RAID 1 (mirror) fails, data can be rebuilt by using the physical disk on the other side of the mirror.

If a physical disk in RAID 5 fails, parity data exists on the remaining physical disks, which can be used to restore the data to a new replacement physical disk configured as a hot spare.

If a physical disk fails in RAID 10, the virtual disk remains functional and data is read from the surviving mirrored physical disk(s). A single disk failure in each mirrored set can be sustained, depending on how the mirrored set fails.

S160 User's Guide, 12.

Automatic virtual disk rebuild

Rebuilds a redundant virtual disk automatically when a failure is detected if a hot spare is assigned for this capability.

S160 User's Guide, 15.

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Assigning the global hot spare disks

A global hot spare disk is a backup physical disk that can be used by any redundant virtual disk. It is not assigned (dedicated) to any specific virtual disk. Virtual disks can typically be rebuilt by using a global spare disk, as long as the global hot spare is not already part of the virtual disk and has enough available capacity. Unlike a dedicated hot spare, a global hot spare can be assigned at anytime, even while tasks are running on virtual disks.

NOTE: A hot spare can be created only if a physical disk is in the **Ready** or **Normal** state in the **Physical Disks** field. If the physical disk is in the **Online** state, the disk is being used by a virtual disk and cannot be selected as a hot spare.

NOTE: If disk space is available in the global hot spare drive then a single global hot spare can be assigned as a hot spare to multiple degraded virtual drives. Therefore, it is possible for the same global hot spare to become part of different degraded virtual drives that have different RAID levels.

Perform the following procedure to assign a global hot spare disk:

1. Enter the **BIOS Configuration utility**. See Entering the BIOS configuration utility.
2. In the **Main Menu** screen, select the **Manage Hot Spare** and press <Enter>.
3. Select **Assign Global Hot Spare(s)**. Press <Enter>.
4. Use the up or down arrow key to select a physical disk(s) to be used as a global hot spare(s). Press <Insert>.
5. Press <Enter> to add the global hot spare.
6. Press the <C> key to confirm the action.

S160 User's Guide, 21.

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Mirror rebuilding

A RAID mirror configuration can be rebuilt after a new physical disk is inserted and the physical disk is designated as a hot spare.

NOTE: The system does not have to be rebooted.

Fault tolerance

The following fault tolerance features are available with the PERC S150:

- Physical disk failure detection (automatic).
- Virtual disk rebuild using hot spares (automatic, if the hot spare is configured for this feature).
- Parity generation and checking (RAID 5 only).
- Hot-swap manual replacement of a physical disk without rebooting the system (only for systems with a backplane that allows hot-swapping).

If one side of a RAID 1 (mirror) fails, data can be rebuilt by using the physical disk on the other side of the mirror.

If a physical disk in RAID 5 fails, parity data exists on the remaining physical disks, which can be used to restore the data to a new replacement physical disk configured as a hot spare.

If a physical disk fails in RAID 10, the virtual disk remains functional and data is read from the surviving mirrored physical disk(s). A single disk failure in each mirrored set can be sustained, depending on how the mirrored set fails.

S150 User's Guide, 12.

Automatic virtual disk rebuild

Rebuilds a redundant virtual disk automatically when a failure is detected if a hot spare is assigned for this capability.

S150 User's Guide, 16.

Mirror rebuilding

A RAID mirror configuration can be rebuilt after a new physical disk is inserted and the physical disk is designated as a hot spare.

S140 User's Guide, "Mirror Rebuilding", 1.

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Dell PowerEdge RAID Controller S140 User's Guide

Fault tolerance

The following fault tolerance features are available with the PERC S140: If one side of a RAID 1 (mirror) fails, data can be rebuilt by using the physical disk on the other side of the mirror.

- Physical disk failure detection (automatic).
- Virtual disk rebuild using hot spares (automatic, if the hot spare is configured for this feature).
- Parity generation and checking (RAID 5 only).
- Hot-swap manual replacement of a physical disk without rebooting the system (only for systems with a backplane that allows hot-swapping).

If a physical disk in RAID 5 fails, parity data exists on the remaining physical disks, which can be used to restore the data to a new replacement physical disk configured as a hot spare.

If a physical disk fails in RAID 10, the virtual disk remains functional and data is read from the surviving mirrored physical disk(s). A single disk failure in each mirrored set can be sustained, depending on how the mirrored set fails.

S140 User's Guide, "Fault Tolerance", 1.

Automatic virtual disk rebuild

Rebuilds a redundant virtual disk automatically when a failure is detected if a hot spare is assigned for this capability.

S140 User's Guide, "Automatic Virtual Disk Rebuild"[18], 1.

[18] Available at https://www.dell.com/support/manuals/en-us/poweredge-rc-s140/s140_ug/automatic-virtual-disk-rebuild?guid=guid-a4195442-08fb-449c-8631-bccc16aad69f&lang=en-us.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

Understanding RAID concepts

Storage Management uses the Redundant Array of Independent Disks (RAID) technology to provide Storage Management capability. Understanding Storage Management requires an understanding of RAID concepts, as well as some familiarity with how the RAID controllers and operating system view disk space on your system.

What is RAID

RAID is a technology for managing the storage of data on the physical disks that reside or are attached to the system. A key aspect of RAID is the ability to span physical disks so that the combined storage capacity of multiple physical disks can be treated as a single, extended disk space. Another key aspect of RAID is the ability to maintain redundant data which can be used to restore data in the event of a disk failure. RAID uses different techniques, such as striping, mirroring, and parity, to store and reconstruct data. There are different RAID levels that use different methods for storing and reconstructing data. The RAID levels have different characteristics in terms of read/write performance, data protection, and storage capacity. Not all RAID levels maintain redundant data, which means for some RAID levels lost data cannot be restored. The RAID level you choose depends on whether your priority is performance, protection, or storage capacity.

NOTE: The RAID Advisory Board (RAB) defines the specifications used to implement RAID. Although RAB defines the RAID levels, commercial implementation of RAID levels by different vendors may vary from the actual RAID specifications. An implementation of a particular vendor may affect the read and write performance and the degree of data redundancy.

Hardware and software RAID

RAID can be implemented with either hardware or software. A system using hardware RAID has a RAID controller that implements the RAID levels and processes data reads and writes to the physical disks. When using software RAID provided by the operating system, the operating system implements the RAID levels. For this reason, using software RAID by itself can slow the system performance. You can, however, use software RAID along with hardware RAID volumes to provide better performance and variety in the configuration of RAID volumes. For example, you can mirror a pair of hardware RAID 5 volumes across two RAID controllers to provide RAID controller redundancy.

Integrated Dell Remote Access Controller 9 User's Guide, 226.

Claim 13	Exemplary Dell '544 Products: Dell PowerEdge Rack Servers (14th, 15th, and 16th Generations[1]) That Use Dell PowerEdge RAID Controllers[2]

RAID concepts

RAID uses particular techniques for writing data to disks. These techniques enable RAID to provide data redundancy or better performance. These techniques include:

- Mirroring — Duplicating data from one physical disk to another physical disk. Mirroring provides data redundancy by maintaining two copies of the same data on different physical disks. If one of the disks in the mirror fails, the system can continue to operate using the unaffected disk. Both sides of the mirror contain the same data always. Either side of the mirror can act as the operational side. A mirrored RAID disk group is comparable in performance to a RAID 5 disk group in read operations but faster in write operations.
- Striping — Disk striping writes data across all physical disks in a virtual disk. Each stripe consists of consecutive virtual disk data addresses that are mapped in fixed-size units to each physical disk in the virtual disk using a sequential pattern. For example, if the virtual disk includes five physical disks, the stripe writes data to physical disks one through five without repeating any of the physical disks. The amount of space consumed by a stripe is the same on each physical disk. The portion of a stripe that resides on a physical disk is a stripe element. Striping by itself does not provide data redundancy. Striping in combination with parity does provide data redundancy.
- Stripe size — The total disk space consumed by a stripe not including a parity disk. For example, consider a stripe that contains 64KB of disk space and has 16KB of data residing on each disk in the stripe. In this case, the stripe size is 64KB and the stripe element size is 16KB.
- Stripe element — A stripe element is the portion of a stripe that resides on a single physical disk.
- Stripe element size — The amount of disk space consumed by a stripe element. For example, consider a stripe that contains 64KB of disk space and has 16KB of data residing on each disk in the stripe. In this case, the stripe element size is 16KB and the stripe size is 64KB.
- Parity — Parity refers to redundant data that is maintained using an algorithm in combination with striping. When one of the striped disks fails, the data can be reconstructed from the parity information using the algorithm.
- Span — A span is a RAID technique used to combine storage space from groups of physical disks into a RAID 10, 50, or 60 virtual disk.

Integrated Dell Remote Access Controller 9 User's Guide, 226-227.

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RAID levels

Each RAID level uses some combination of mirroring, striping, and parity to provide data redundancy or improved read and write performance. For specific information on each RAID level, see Choosing raid levels.

Organizing data storage for availability and performance

RAID provides different methods or RAID levels for organizing the disk storage. Some RAID levels maintain redundant data so that you can restore data after a disk failure. Different RAID levels also entail an increase or decrease in the I/O (read and write) performance of a system.

Maintaining redundant data requires the use of additional physical disks. The possibility of a disk failure increases with an increase in the number of disks. Since the differences in I/O performance and redundancy, one RAID level may be more appropriate than another based on the applications in the operating environment and the nature of the data being stored.

When choosing a RAID level, the following performance and cost considerations apply:

- **Availability or fault-tolerance** — Availability or fault-tolerance refers to the ability of a system to maintain operations and provide access to data even when one of its components has failed. In RAID volumes, availability or fault-tolerance is achieved by maintaining redundant data. Redundant data includes mirrors (duplicate data) and parity information (reconstructing data using an algorithm).
- **Performance** — Read and write performance can be increased or decreased depending on the RAID level you choose. Some RAID levels may be more appropriate for particular applications.
- **Cost efficiency** — Maintaining the redundant data or parity information associated with RAID volumes requires additional disk space. In situations where the data is temporary, easily reproduced, or non-essential, the increased cost of data redundancy may not be justified.
- **Mean Time Between Failure (MTBF)** — Using additional disks to maintain data redundancy also increases the chance of disk failure at any given moment. Although this option cannot be avoided in situations where redundant data is a requirement, it does have implications on the workload of the system support staff within your organization.
- **Volume** — Volume refers to a single disk non-RAID virtual disk. You can create volumes using external utilities like the O-ROM <Ctrl> <r>. Storage Management does not support the creation of volumes. However, you can view volumes and use drives from these volumes for creation of new virtual disks or Online Capacity Expansion (OCE) of existing virtual disks, provided free space is available.

Integrated Dell Remote Access Controller 9 User's Guide, 227.